

***HQ AFWA/XOGX  
Space Weather Branch  
Space Weather Support to  
Warfighters***



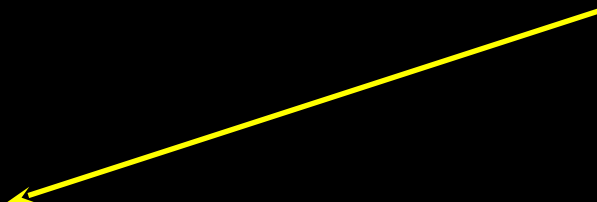
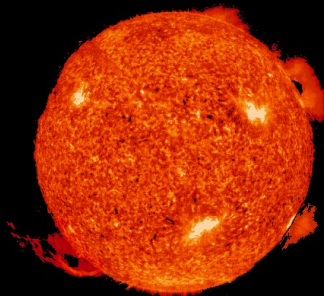
- ELECTROMAGNETIC RADIATION
- ENERGETIC PARTICLES
- ELECTRICALLY CHARGED  
PARTICLE CLOUDS
- SCINTILLATION



# ***ELECTROMAGNETIC RADIATION***



# ***ELECTROMAGNETIC RADIATION***



## **Electromagnetic Radiation**

**ARRIVAL: 8 min**

**DURATION: 1-2 HOURS**

### **EFFECTS**

- **HF RADIO BLACKOUT**
- **SATCOM  
INTERFERENCE**
- **RADAR  
INTERFERENCE**
- **SATELLITE ORBIT**



# ***ELECTROMAGNETIC RADIATION***

## ***HF RADIO BLACKOUT***

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### ***SHORT-WAVE FADE***

- Abnormally high fade or absorption of HF radio signals caused by solar flare.
- Flare enhances D-layer density, causing absorption.
- Affects frequencies from 300kHz to 30MHz
- Only affects communications through sun-lit sector of the earth
- EUV and X-ray enhanced up to 100 times
- Lowest Usable Frequency (LUF) becomes higher than the Maximum Usable Frequency (MUF), severely degrading or completely cutting off HF communications.



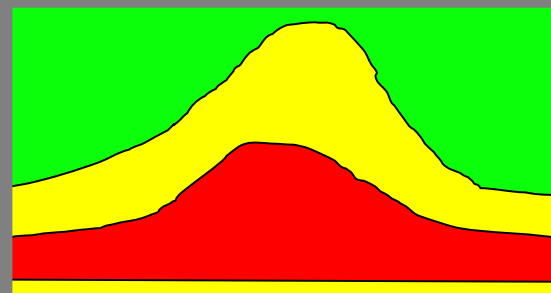
# ***ELECTROMAGNETIC RADIATION***

## ***HF RADIO BLACKOUT***

**Undisturbed  
Ionosphere**



**NORMAL CONDITIONS**



**F**

**E**

**D**

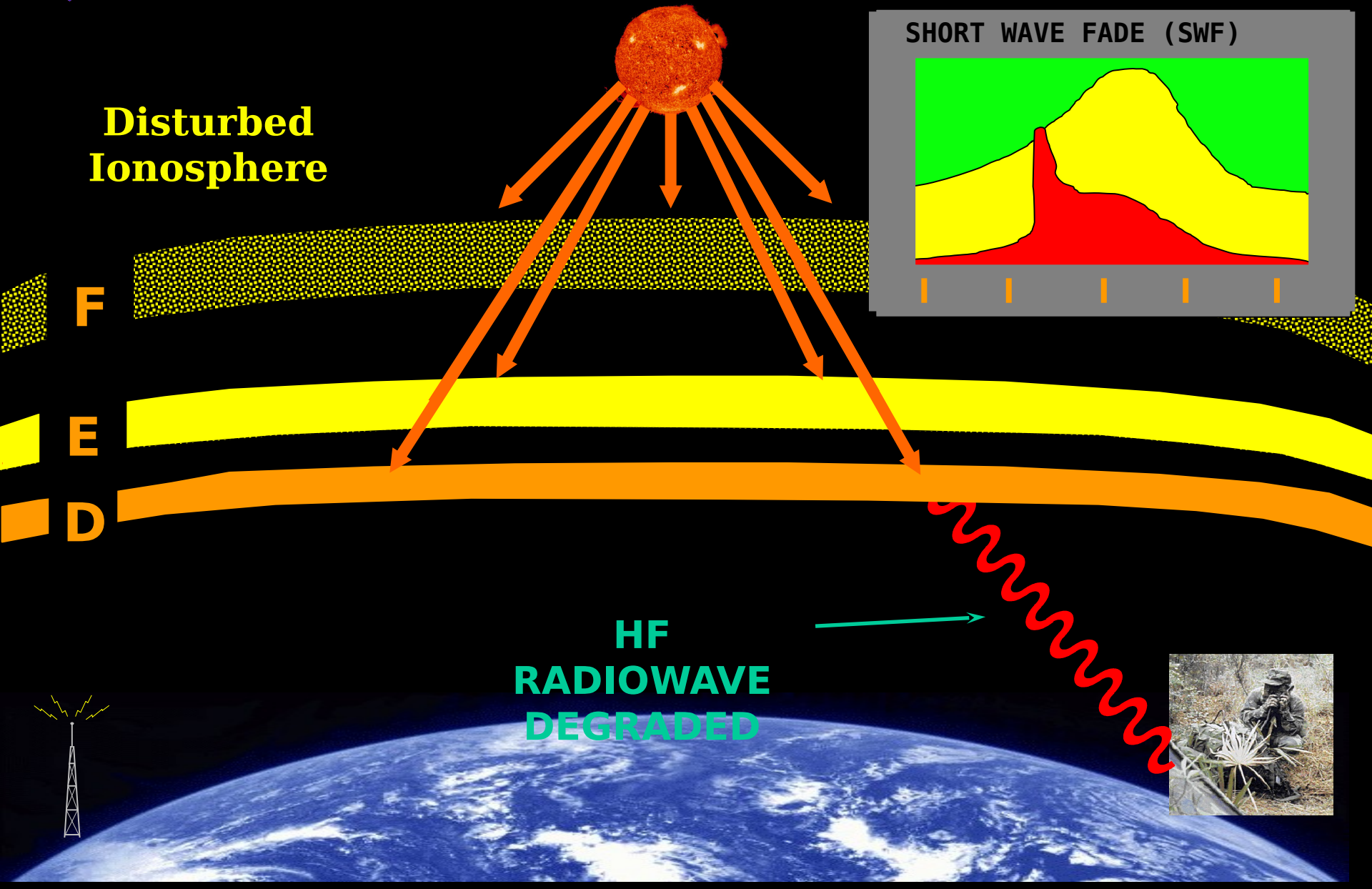
**HF  
RADIOWAVE  
NORMAL  
CONDITIONS**





# ***ELECTROMAGNETIC RADIATION***

## ***HF RADIO BLACKOUT***





# ***SATCOM & RADAR INTERFERENCE***

- Lasts from a few minutes to hours
- Generally the larger the flare, the greater intensity the radio burst
- Only affects the sun-lit sectors of the earth
- Radio bursts directly interfere with the radar signals, causing false returns or false targeting
- Satcom also impacted due to signal interference and loss

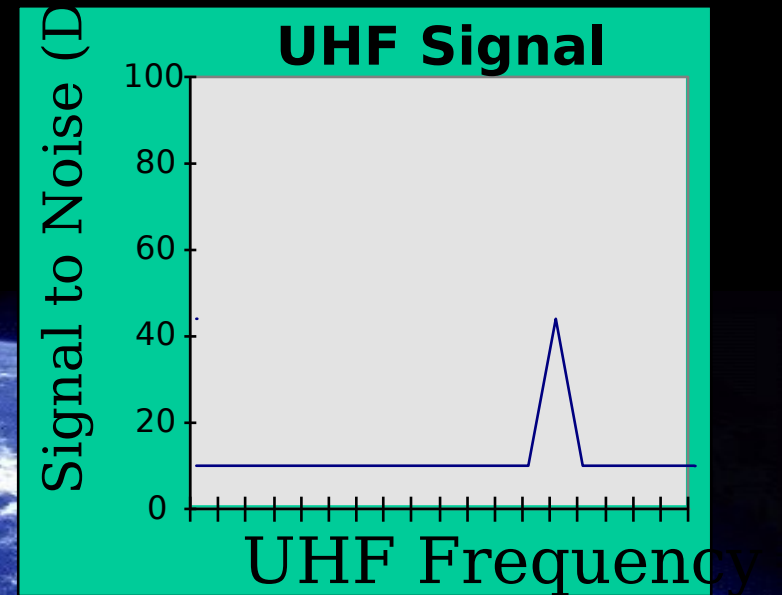
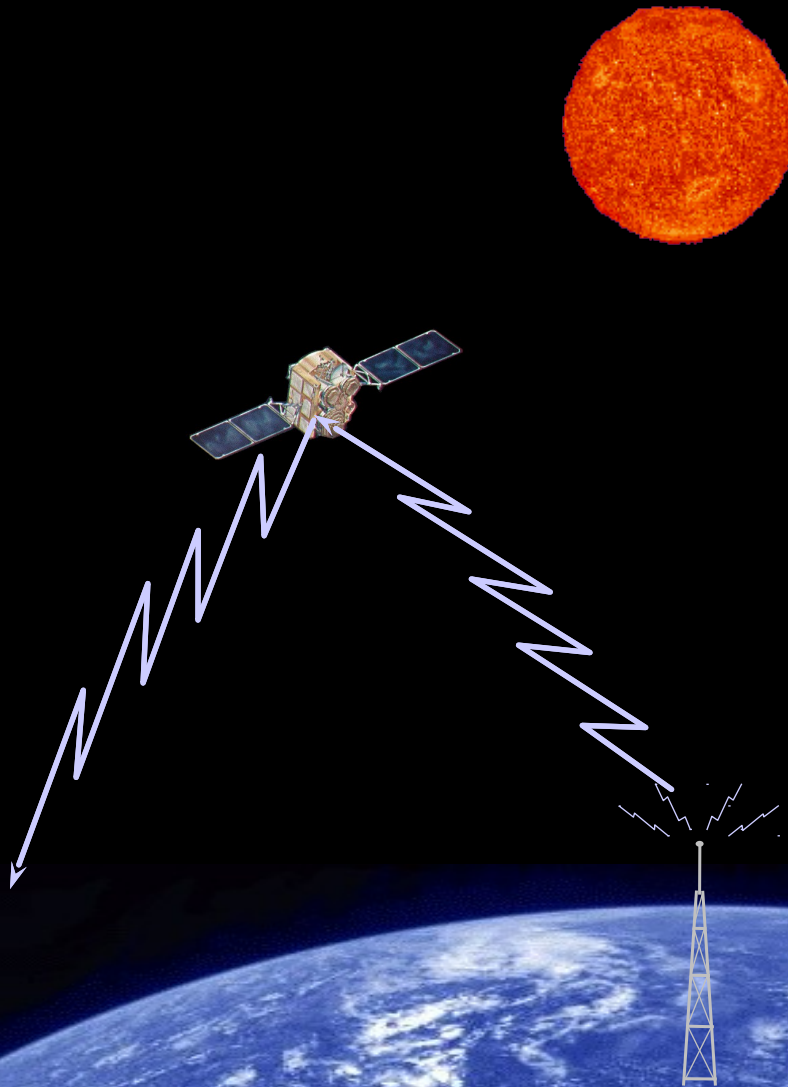




# ***ELECTROMAGNETIC RADIATION***

## ***SATCOM INTERFERENCE***

**UHF and SHF  
SATCOM under  
normal space  
weather  
conditions**



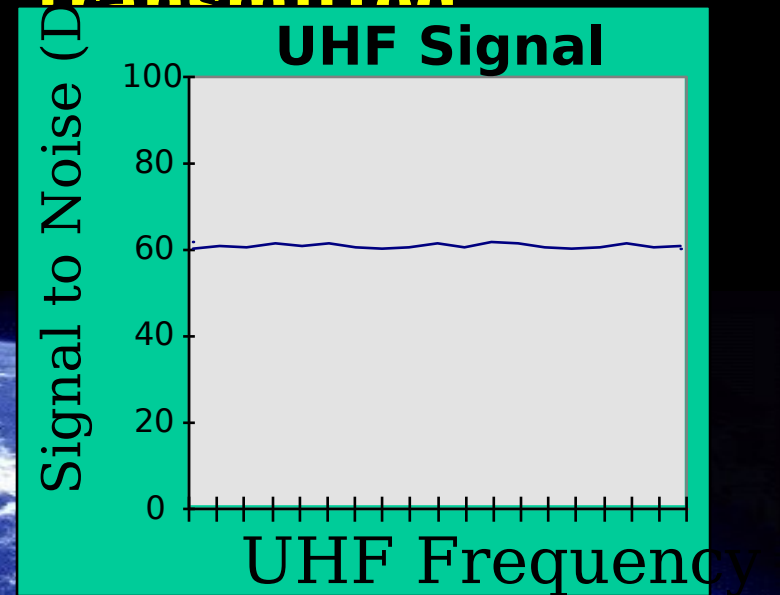
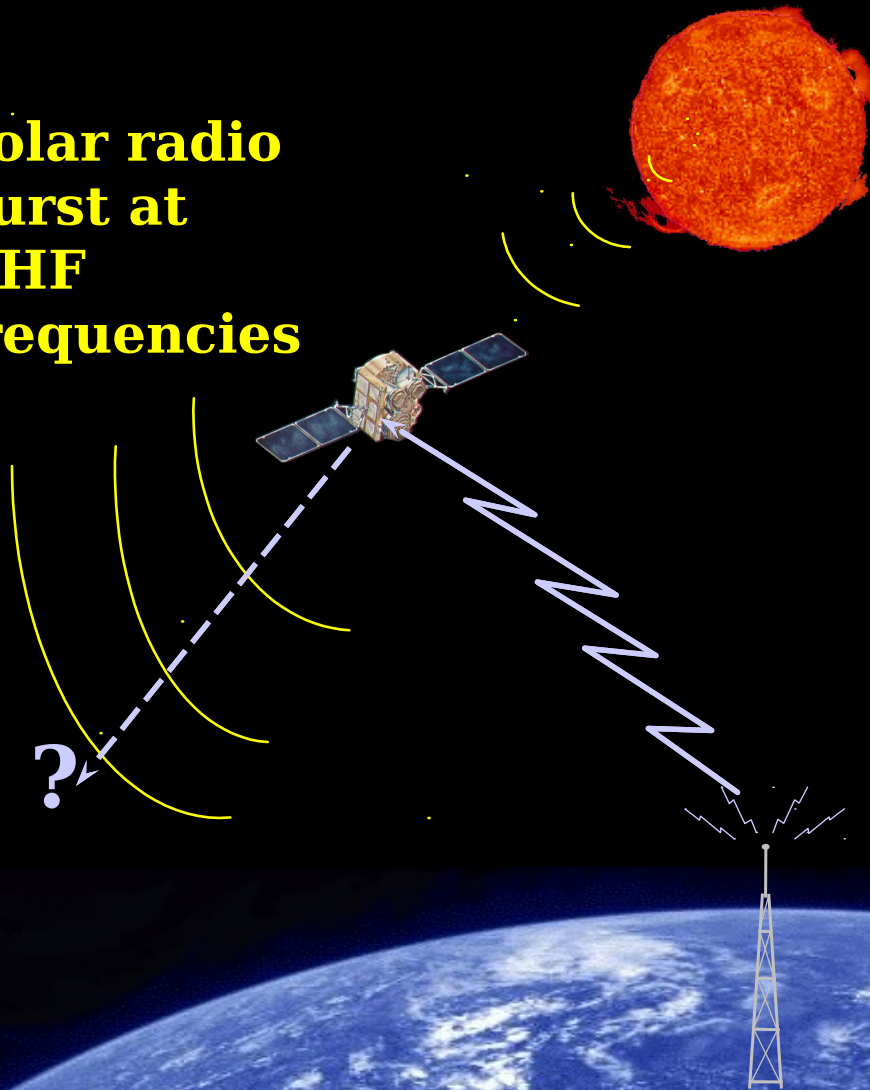


# ***ELECTROMAGNETIC RADIATION***

## ***SATCOM INTERFERENCE***

**Solar radio  
burst at  
UHF  
frequencies**

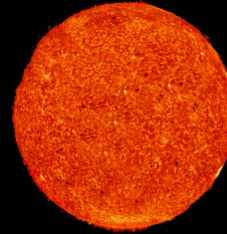
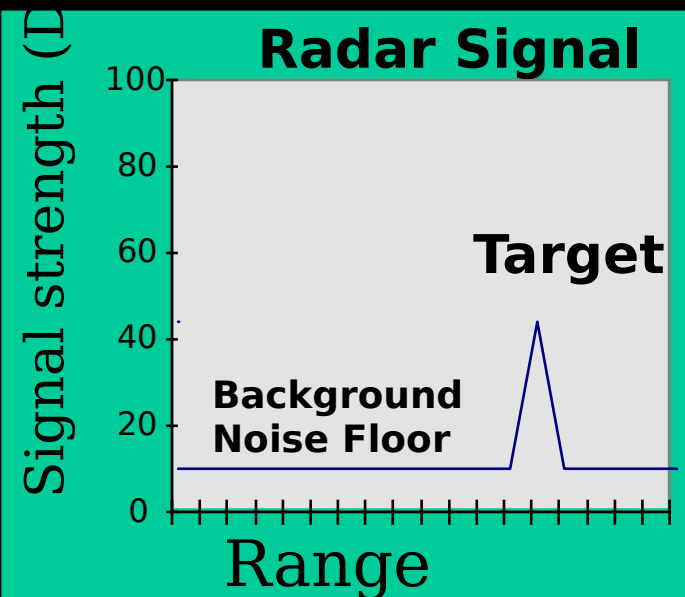
**Solar emissions  
during radio  
bursts can be as  
much as 100-  
1000 times the  
strength of  
transmitted**





# ***ELECTROMAGNETIC RADIATION***

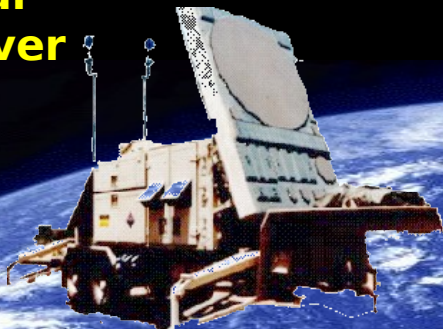
## ***RADAR INTERFERENCE***



**Sun emitting  
background  
UHF radio noise**



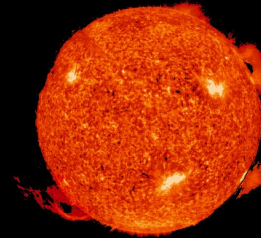
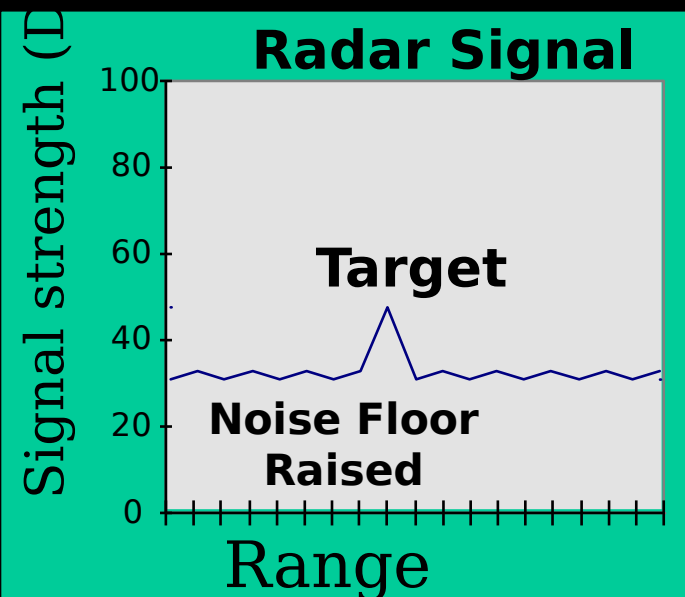
**Radar  
Receiver**





# ***ELECTROMAGNETIC RADIATION***

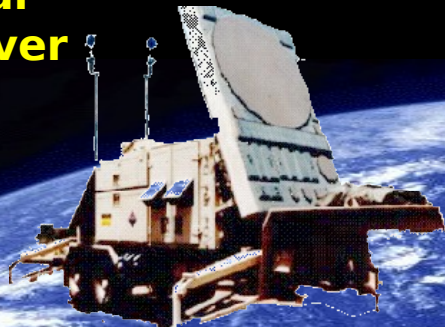
## ***RADAR INTERFERENCE***



**Solar radio burst  
UHF frequencies**



**Radar  
Receiver**

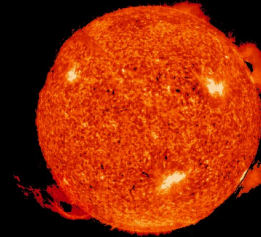
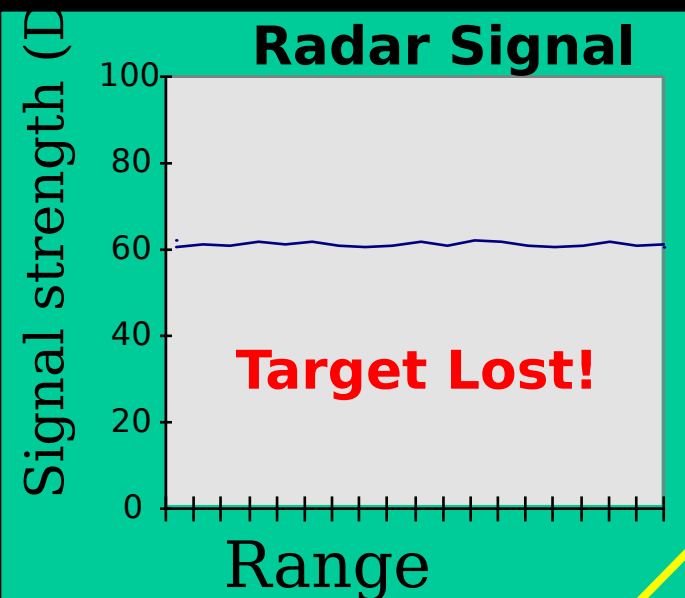




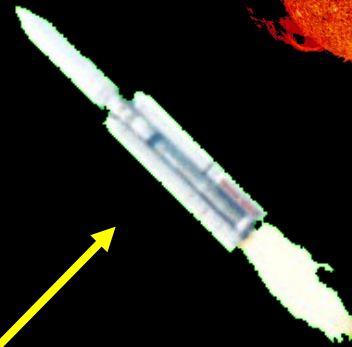


# ***ELECTROMAGNETIC RADIATION***

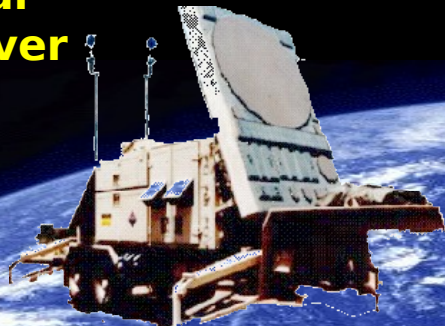
## ***RADAR INTERFERENCE***



**Solar radio burst  
UHF frequencies**



**Radar  
Receiver**

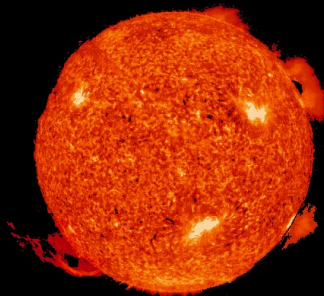




# ***ENERGETIC PARTICLES***



# ENERGETIC PARTICLES



## Electromagnetic Radiation

ARRIVAL: 8 min

DURATION: 1-2 HOURS

### EFFECTS

- HF RADIO BLACKOUT
- SATCOM INTERFERENCE
- RADAR INTERFERENCE
- SATELLITE ORBIT DECAY

## High Energy Charged Particles

ARRIVAL: 15 MIN TO FEW HOURS

DURATION: DAYS

### EFFECTS

- HIGH-LATITUDE HF RADIO BLACKOUT
- SATELLITE DISORIENTATION
- SPACECRAFT DAMAGE
- LAUNCH PAYLOAD FAILURE

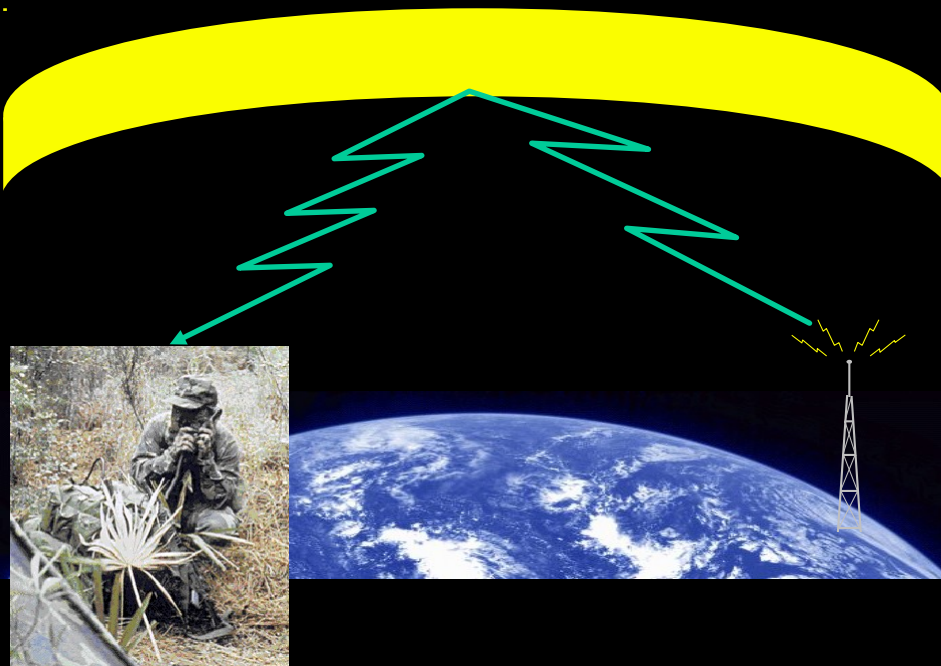


# ***ENERGETIC PARTICLES***

## ***POLAR CAP ABSORPTION***

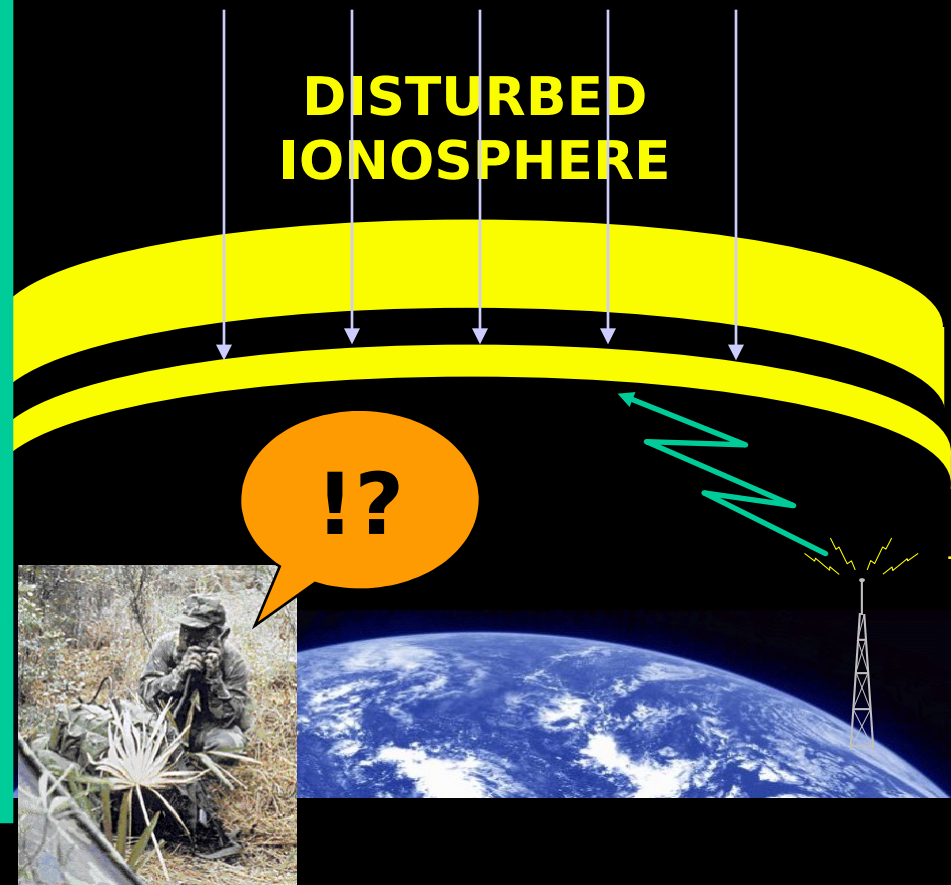
Particles enter the polar cap and are absorbed,  
severely degrading communications at all  
frequencies

**UNDISTURBED  
IONOSPHERE**



**POLAR CAP ABSORPTION**

**DISTURBED  
IONOSPHERE**



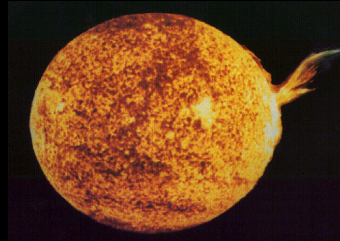




# ***ENERGETIC PARTICLES***

## ***SATELLITE DISORIENTATION***

Protons can be mistaken for stars by satellite guidance systems, causing disorientation



**PARTICLE  
STREAM  
(PROTONS)**

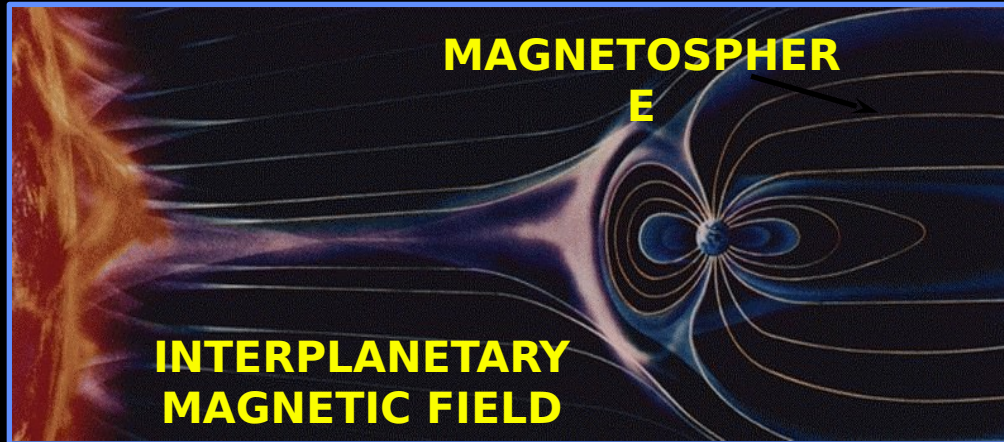
**FALSE STAR ?**





# ***ENERGETIC PARTICLES***

## ***SPACECRAFT DAMAGE AND SINGLE EVENT UPSETS***



HIGH ENERGY PROTON  
CAN PENETRATE  
COMPLETELY THROUGH  
SATELLITE AND IONIZE  
MATERIAL DEEP INSIDE

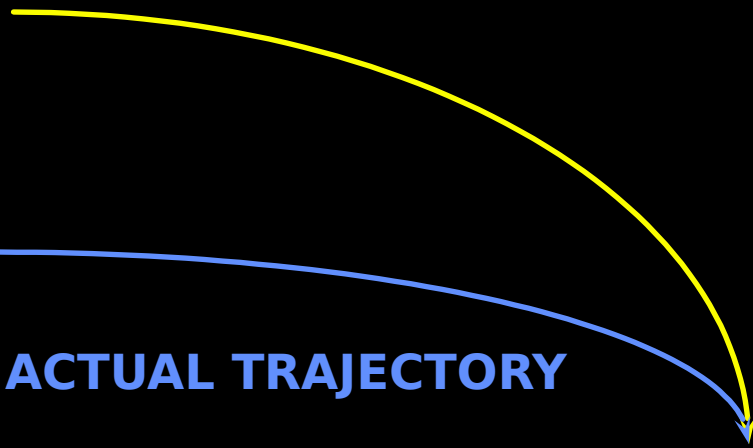
RESULT - SINGLE  
PARTICLE CAN CAUSE  
PHYSICAL DAMAGE  
AND/OR DEPOSIT  
ENOUGH CHARGE TO  
CAUSE AN ELECTRICAL  
UPSET (CIRCUIT SWITCH,  
FALSE COMMAND, OR  
MEMORY CHANGE/LOSS)  
OR PHYSICAL DAMAGE



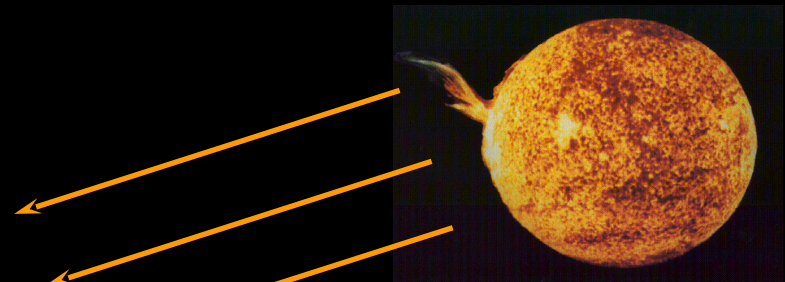
# **ENERGETIC PARTICLES**

## **LAUNCH TRAJECTORY ERRORS & PAYLOAD DEPLOYMENT PROBLEMS**

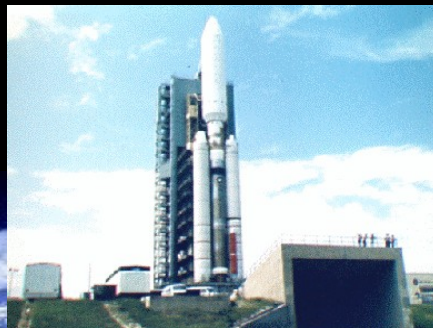
**EXPECTED TRAJECTORY**



**ACTUAL TRAJECTORY**



**CHARGED PARTICLES**





# ***ENERGETIC PARTICLES***

## ***RADIATION EXPOSURE***

- Causes direct radiation hazard to astronauts and high altitude aircrews
- Can penetrate shielding
  - Physical damage to equipment and personnel



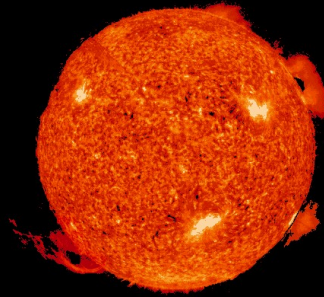




# ***ELECTRICALLY CHARGED PARTICLE CLOUD***



# ***ELECTRICALLY CHARGED PARTICLE CLOUD***



## **Electromagnetic Radiation**

**ARRIVAL: 8 min  
DURATION: 1-2 HOURS**

### **EFFECTS**

- **HF RADIO BLACKOUT**
- **SATCOM INTERFERENCE**
- **RADAR INTERFERENCE**
- **SATELLITE ORBIT DECAY**

## **High Energy Charged Particles**

**ARRIVAL: 15 MIN TO FEW  
HOURS  
DURATION: DAYS**

### **EFFECTS**

- **HIGH-LATITUDE HF RADIO BLACKOUT**
- **SATELLITE DISORIENTATION**
- **SPACECRAFT DAMAGE**
- **FALSE SENSOR READINGS**

## **Electrically Charged Particle Clouds**

**ARRIVAL: 2-3 DAYS**

### **EFFECTS**

- **HF RADIO BLACKOUT**
- **SATELLITE ORBIT DECAY**
- **RADAR FALSE TARGETS**



# ***ELECTRICALLY CHARGED PARTICLE CLOUD EFFECTS***

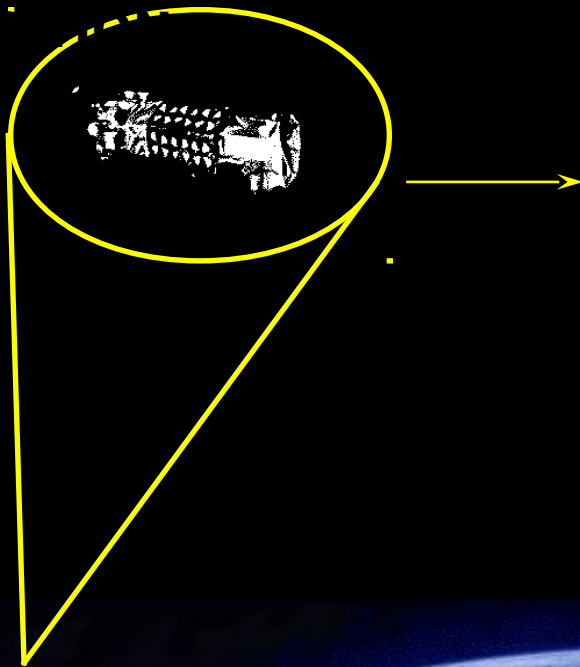
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- **Anomalous propagation of HF and Satellite Communications**
- **Satellite orbit changes due to friction**
- **Radar signals reflect, distort, or slow**
- **Aurora Radar clutter and target masking**



# ***ELECTRICALLY CHARGED PARTICLE CLOUD EFFECTS SATELLITE ORBIT CHANGES***

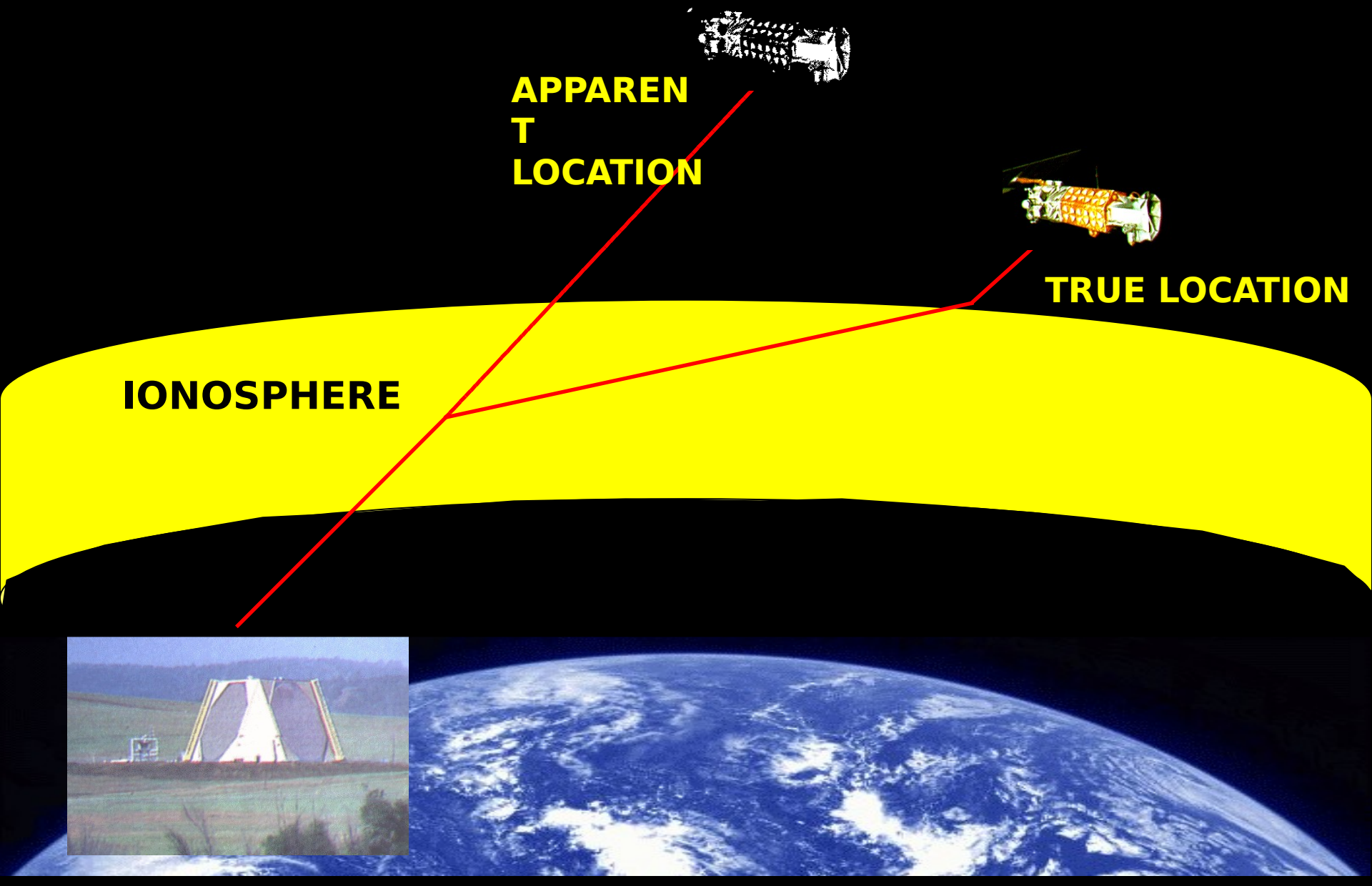
The ionosphere expands enough where it increases the particle density that the LEO satellites orbit through, this increase in density increases friction which slows the spacecraft down which changes its orbit.







# ***ELECTRICALLY CHARGED PARTICLE CLOUD EFFECTS RADAR FALSE TARGETS***

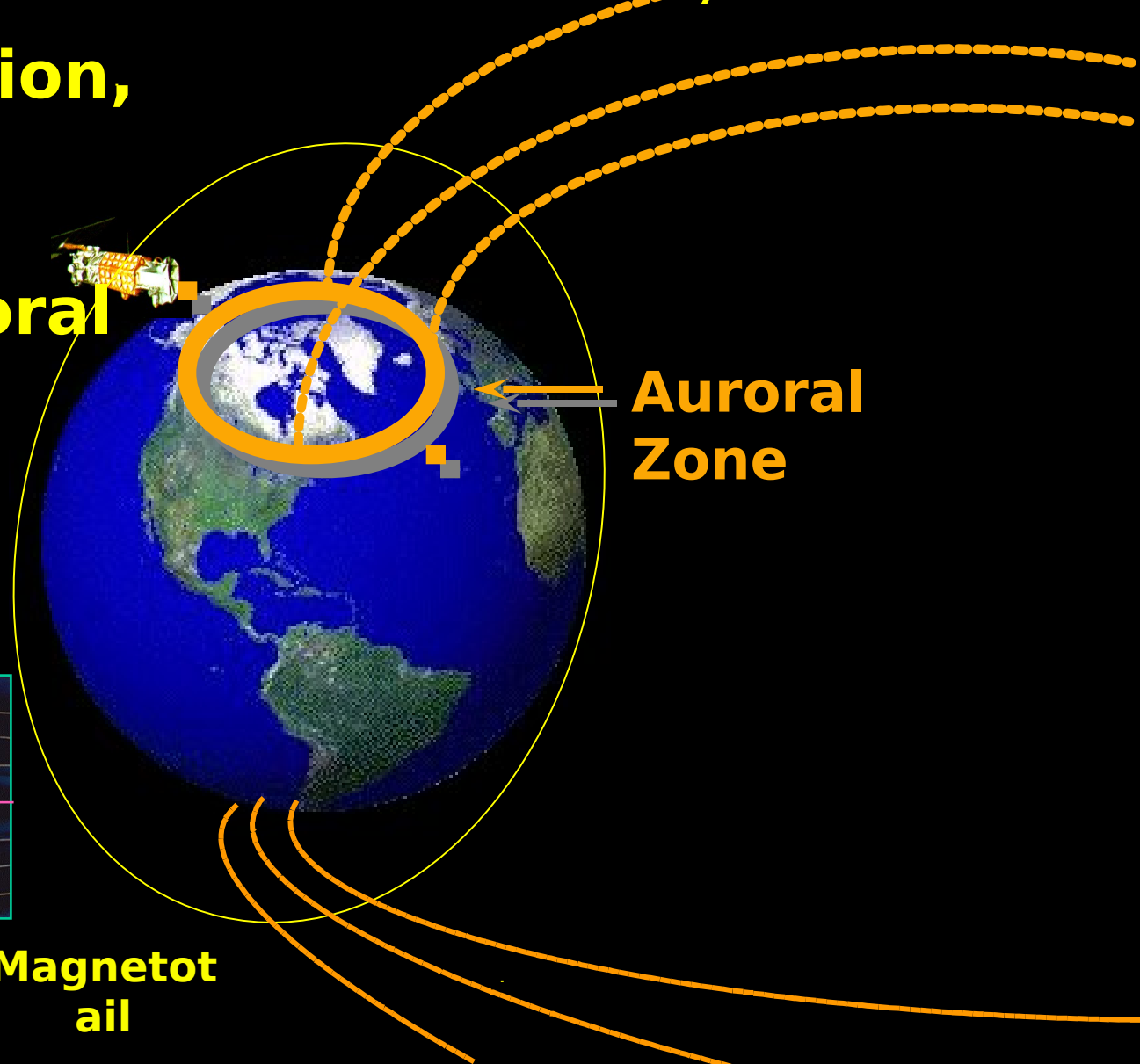




# ***ELECTRICALLY CHARGED PARTICLE CLOUD EFFECTS***

## ***IONOSPHERIC ENHANCEMENT / DEPLETION***

**High inclination,  
low altitude  
orbits pass  
through auroral  
zones**

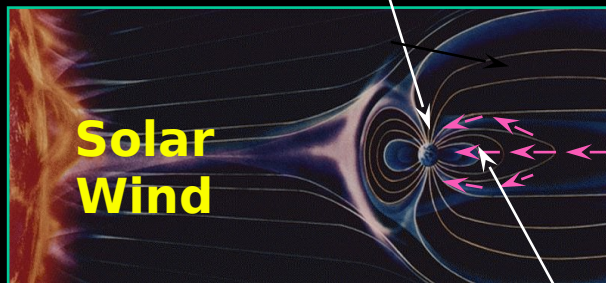


**Polar  
Cusp**

**Solar  
Wind**

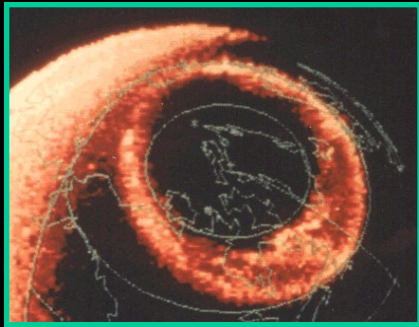
**Magnetosphere**

**Magnetotail**





# ***ELECTRICALLY CHARGED PARTICLE CLOUD EFFECTS RADAR INTERFERENCE***



**RADAR  
AURORA**



**Ionosphere**

**Signal Reflected/Distorted**





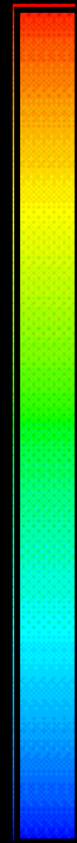
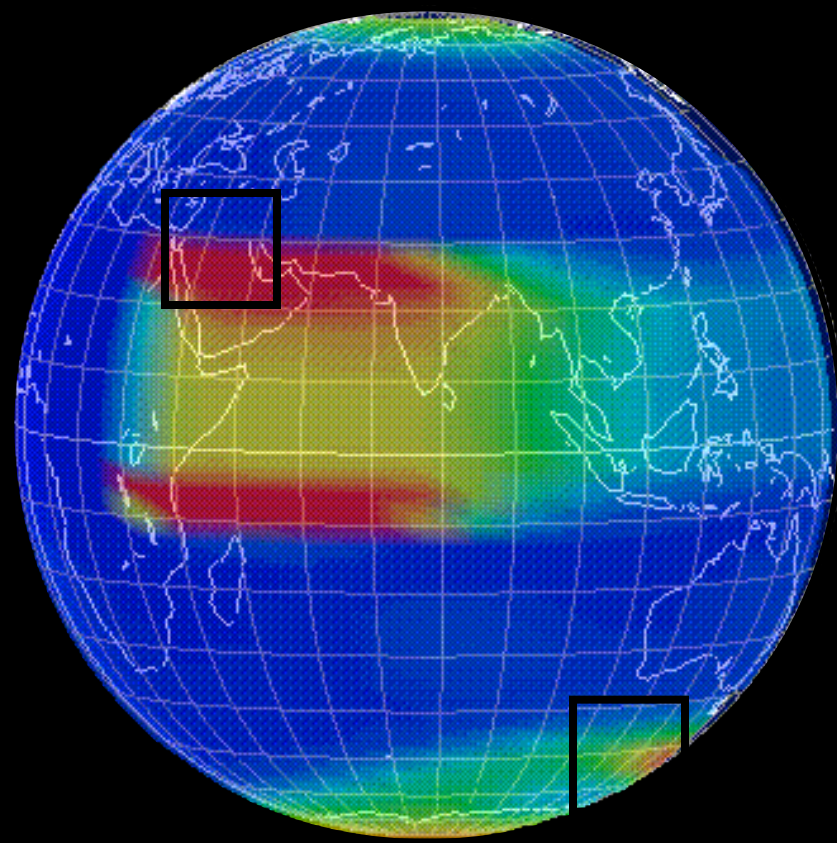
- Rapid, random variation in signal amplitude
  - small scale irregularities in electron density
  - Example: twinkling of starlight
- Mid-latitudes and northern polar regions
- Nighttime sectors





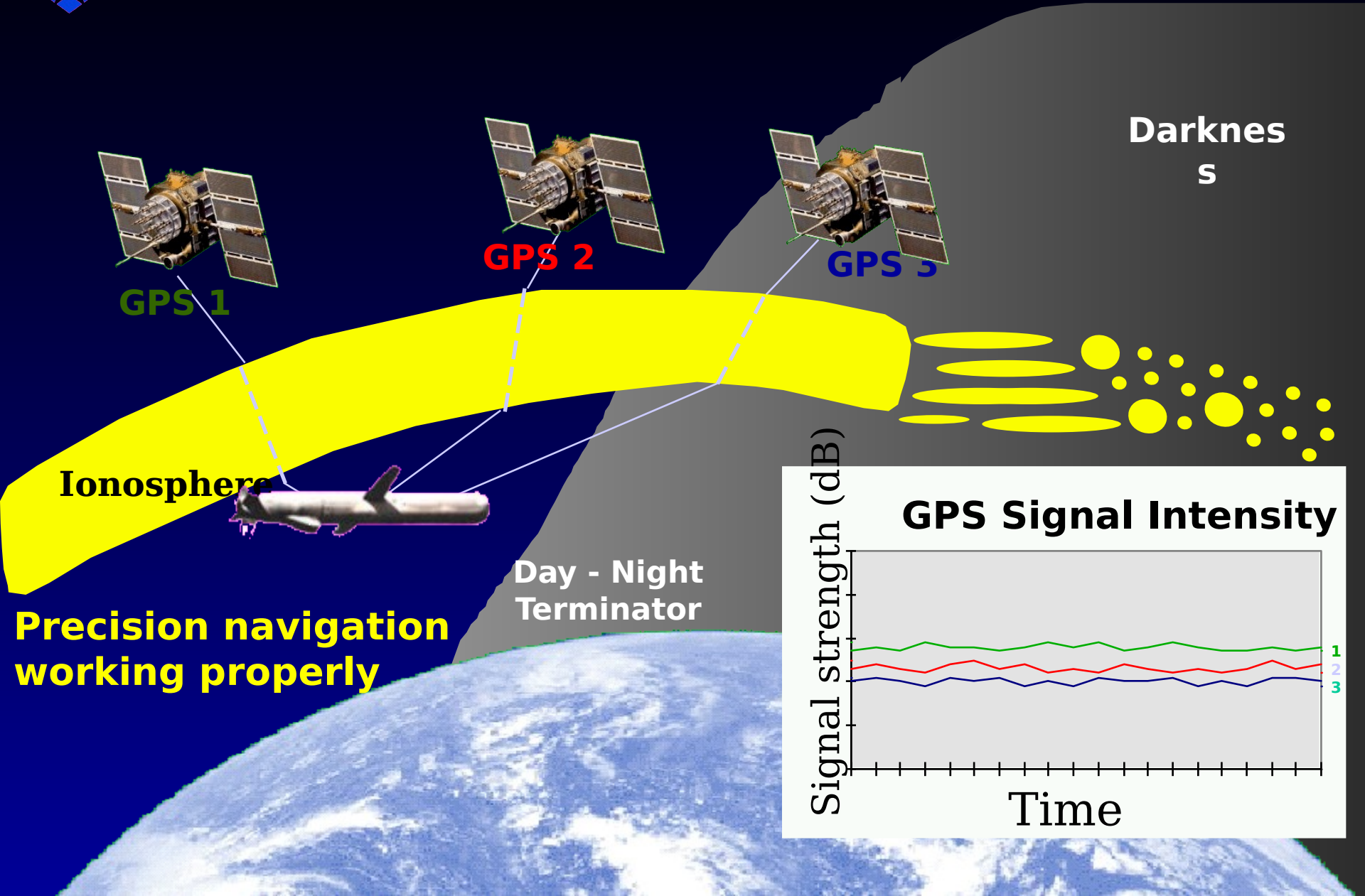
# SCINTILLATION

## Sample Scintillation





# SCINTILLATION



Darkness

GPS 2

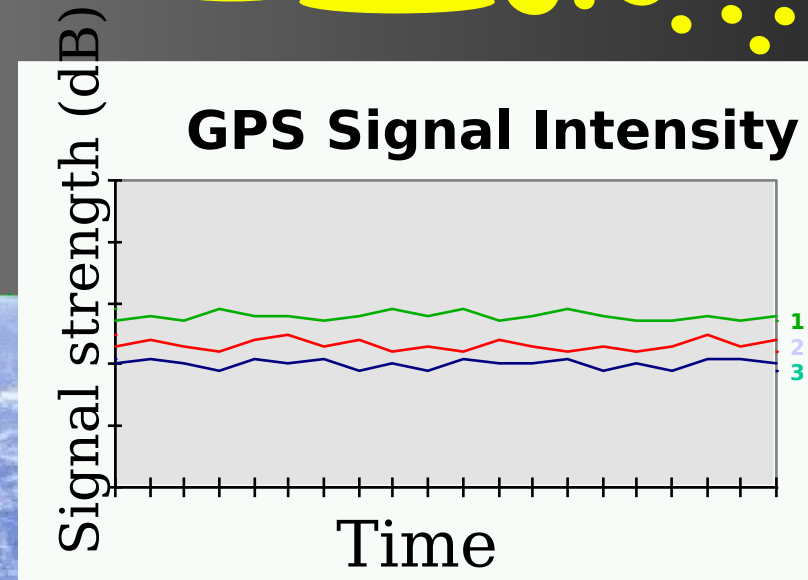
GPS 3

GPS 1

Ionosphere

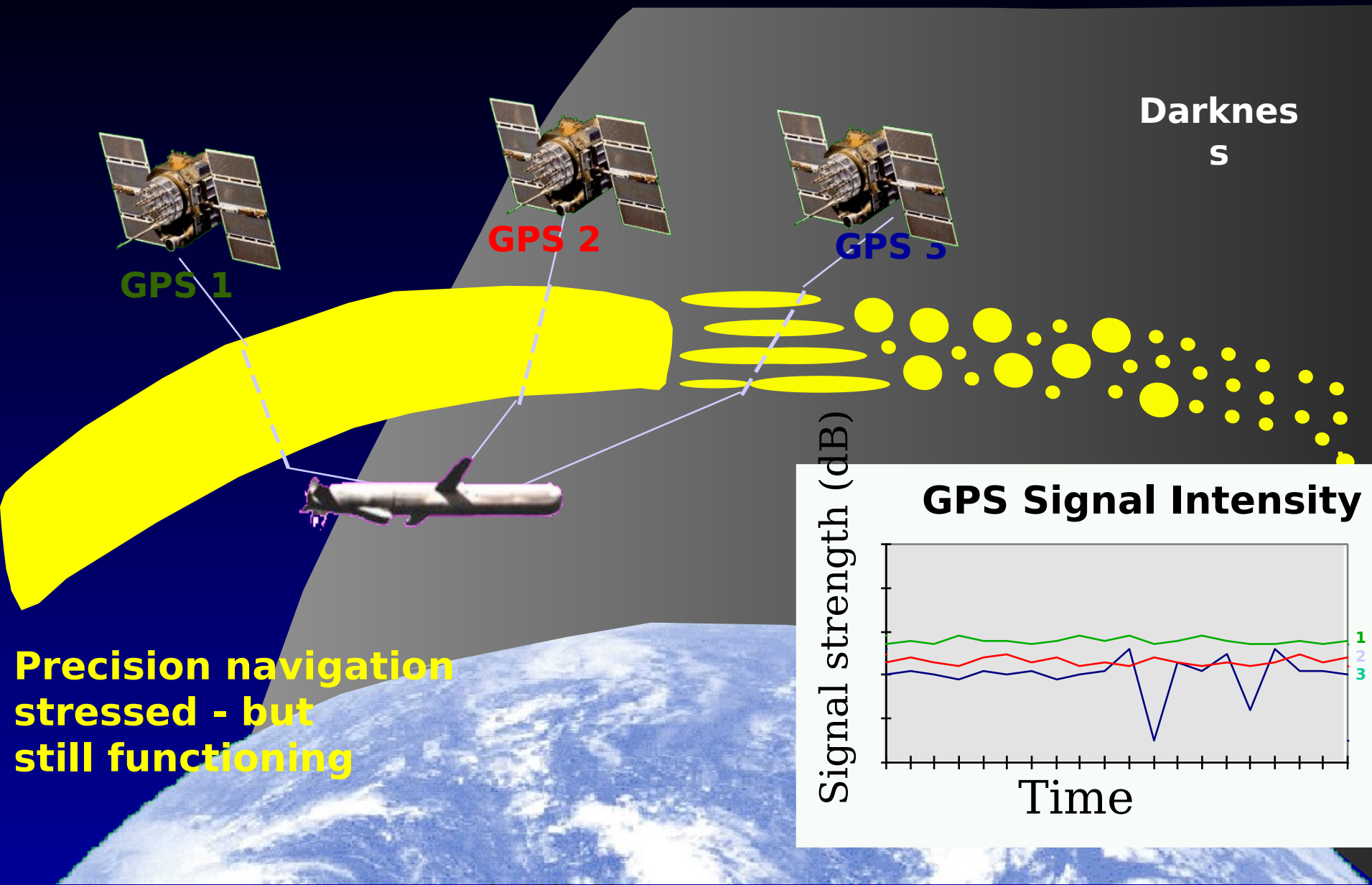
Day - Night Terminator

Precision navigation working properly



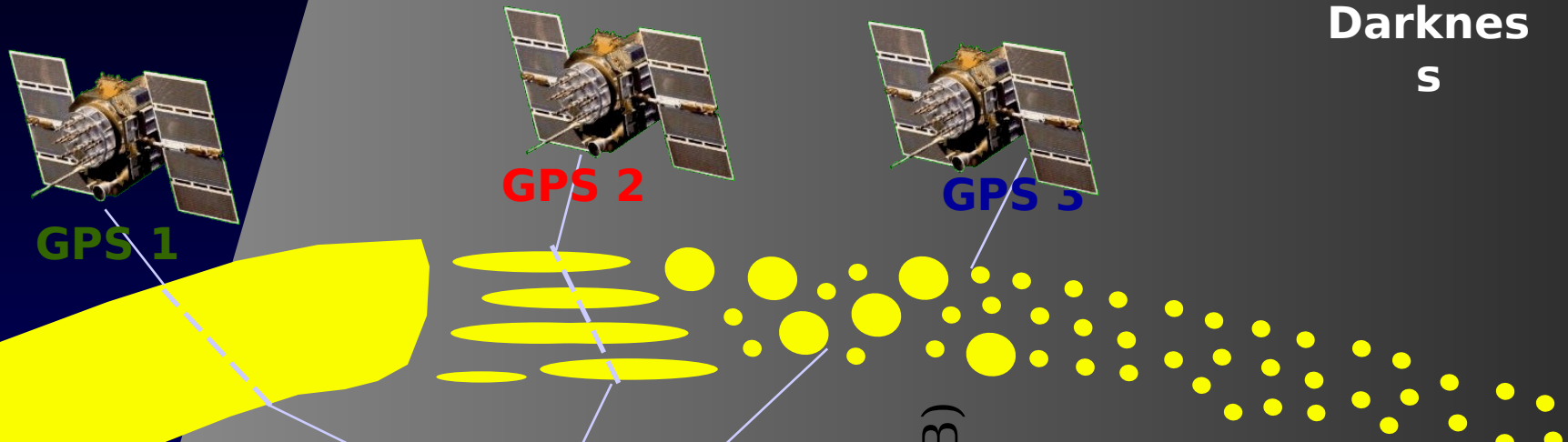


# SCINTILLATION





# SCINTILLATION



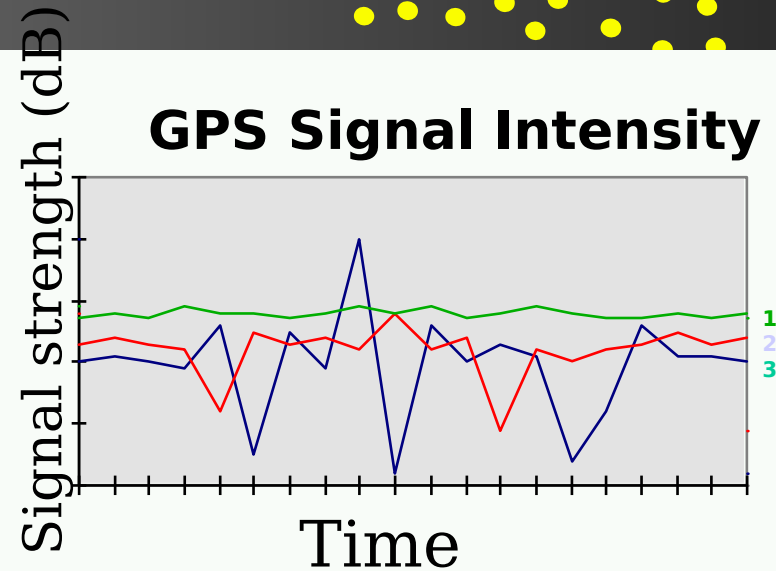
Darkness

GPS 1

GPS 2

GPS 3

Precision navigation  
significantly degraded  
due to position errors







## **SOLAR FLARE AND/OR RADIO BURST EFFECTS**

- HF Radio Blackout
- SATCOM Interference
- Radar Interference
- Satellite Orbit Decay



## **PROTON EFFECTS**

- **Aircrew Health**
- **Spacecraft Damage**
- **Launch Payload Failure**
- **HF Radio Blackout (Polar Cap Absorption)**
- **Satellite Disorientation**



## **GEOMAGNETIC STORMING EFFECTS**

- HF Radio Blackout
- Radar False Targets
- Satellite Orbit Decay



# ***Training and Contact Information***

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## ***HQ AFWA/DNT Training Web Site***

[https://wwwmil.offutt.af.mil/afwadnt/space\\_weather.htm](https://wwwmil.offutt.af.mil/afwadnt/space_weather.htm)

## ***Documentation:***

**AFSPCPAM 15-2**

## ***Questions contact:***

**HQ AFWA/XOGX**

**DSN 272-8087 Fax - 272-6557**

**Commercial (402) 232- 8087 Fax 6557**

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